Executive Summary

BACKGROUND

Since the end of the Cold War, funding for the acquisition of new U.S. military aircraft has become scarce, and after plunging precipitously in the early 1990s, budgets for the modernization of the existing ("legacy") fleet have remained flat. The operational lifetimes of legacy aircraft are being extended well beyond their original design lifetimes, and the average age of U.S. military aircraft is 20 years and increasing. In the 1990s, the U.S. Air Force reported that the mission capability of its aircraft declined by 10 percentage points—from 83 percent to 73 percent. This decline in readiness was due largely to the increasing age of the aircraft fleet, particularly the aging avionics systems upon which the aircraft depend. This trend applies to most military equipment, not just aircraft. As defined in this report, the term "avionics" includes internal electronic hardware, as well as external pods for systems, such as electronic countermeasures. The term "aging" refers to technical obsolescence, as well as physical degeneration over time.

There is widespread agreement that U.S. military forces must be modernized to meet the challenges of the twenty-first century. The critical need to upgrade avionics systems to meet evolving changes in threats, missions, and peacetime air traffic control requirements, especially at a time when very few new programs are being started, should have a high priority. However, the U.S. Department of Defense (DoD) has been caught in a vicious cost spiral that links the costs of modernization with constantly increasing support costs. Because of a relatively flat total budget, the funds needed for modernization are being siphoned off for increasing support costs, which will continue to increase as the equipment ages. This trend must be reversed.

Extending the life of an airframe has proven challenging and costly. Extending the life of an avionics system, however, is one of the most critical and difficult aspects of extending total aircraft system lifetimes. Critical components go out of production or become obsolete, and many former suppliers of military-grade components have gone out of business. From 1986 to 1996, for example, the percentage of discontinued military/aerospace electronic devices nearly doubled—from 7.5 percent to 13.5 percent. In addition, legacy avionics systems, which were designed to meet requirements of the past, generally lack the full capability to perform new missions, meet new threats, or perform well in the new information-intensive battlefield environments.

As the legacy aircraft fleet ages, avionics systems will become more and more difficult to support and maintain. Whereas the military once provided a large and profitable market for the electronics industry, the military electronics market today constitutes less than 1 percent of the commercial market. As a result, the

military must increasingly rely on commercial off-the-shelf (COTS) technologies for its avionics hardware and software. Although COTS items are generally less expensive than comparable items designed especially to meet military specifications, the technology-refresh cycle for COTS is typically 18 months or less, which exacerbates the obsolescence problem for aircraft whose lifetimes are measured in decades. The short refresh cycle is driven mostly by the tremendous advances in computer systems, which comprise an increasing percentage of avionics content.

When a new aircraft is designed, the latest advances in avionics technology can be used, and strategies for managing obsolescence can and should be built in from the beginning. However, long weapon-system development and procurement cycles virtually guarantee that some avionics systems will be obsolete by the time they are fielded. The F-22 Raptor program, for example, which began nearly 20 years ago, is still at least five years away from fielding aircraft in squadron strength. The program now budgets $50 million a year to replace "old" avionics with new hardware and software. By the time the first production F-22 rolls off the line, its avionics systems will have undergone four technology-refresh cycles.

According to Lt. General Robert Raggio, Commander of the Aeronautical Systems Center, the Air Force needs an additional $250 million to $275 million per year to address the aging avionics problem in both legacy and new aircraft, not including the cost of training maintenance personnel, suppliers, and operators. Each technology-refresh cycle requires regression testing and flight testing, training for pilots and support personnel, and configuration and spares management, which all add to the implementation cost. Cumulative costs for diminishing manufacturing sources/out-of-production parts (DMS/OP) are projected to reach close to $1 billion each for the F-15, F-22, and U-2.

Without a coherent strategy for managing and containing the total ownership cost (TOC) of avionics systems, both for legacy and new aircraft, the maintenance of these systems will demand an ever-increasing share of the Air Force budget. Managing the DMS/OP problem alone is consuming a larger and larger portion of aircraft program office budgets. If overall DoD budgets remain flat, expenditures on DMS/OP threaten to consume funds that would otherwise be spent on modernizing the aircraft fleet and bringing operational capabilities up to the levels required to counter evolving threats.

STATEMENT OF TASK

In response to a request by the Assistant Secretary of the Air Force for Acquisition, the National Research Council convened the Committee on Aging Avionics in Military Aircraft, under the auspices of the Air Force Science and Technology Board, to conduct this study. The study committee was given the following tasks:

- Gather information from DoD, other government agencies, and industrial sources on the status of, and issues surrounding, the aging avionics problem. This should include briefings from and discussions with senior industry executives and military acquisition and support personnel. A part of this activity should include a review of Air Force Materiel Command's study on diminishing manufacturing sources to recommend ways to mitigate avionics obsolescence.
- Provide recommendations for new approaches and innovative techniques to improve management of aging avionics, with the goal of helping the Air Force to enhance supportability and replacement of aging and obsolescing avionics and minimize associated life cycle costs. Comment on the division of technology responsibility between DoD and industry.

MANAGEMENT OF AVIONICS SYSTEMS

The committee recognizes that there are many dimensions and/or objectives in any strategy for managing the total DMS/OP problem and that individual corrective actions for a particular aircraft platform will depend on the specific characteristics of its installed avionics systems. More than 25 organizations, both inside and outside the Air Force, are working on various aspects of the DMS/OP problem. Although each organization is effective in its limited chartered activities, there is very little coordination among them, and the results of each project are not broadly distributed to the DoD or to the Air Force Enterprise. With a coherent DoD/Air Force strategy for dealing with the DMS/OP problem, collective/coordinated management of these diverse activities could be established, which could result in more productive use of results and minimal redundant expenditures of scarce resources.

A modular open-system approach (MOSA) has been endorsed by the Air Force as a way of developing scalable, more easily upgradable avionics systems and reducing TOCs in both legacy and new aircraft. The

committee generally agrees that, if MOSA principles were judiciously applied to new systems and to the updates of legacy platforms, the TOC of avionics systems could be significantly reduced. However, mitigating the aging avionics problem will require more than new technical approaches. Broader issues having to do with DoD management, congressional budgets, and DoD's relationships with its contractors must also be addressed. These issues, as well as the narrower technical issues, are addressed in the following findings and recommendations.

FINDINGS AND RECOMMENDATIONS

Based on testimony from a broad cross section of government managers who are attempting to address the DMS/OP problem for legacy aircraft and new aircraft/avionics subsystems and a broad cross section of prime contractors and subsystem suppliers, who discussed the problem from a private sector viewpoint, the committee arrived at the following findings and recommendations. Note that the committee members were convinced that mitigating the aging avionics problem will require more than new technical approaches and that dealing effectively with the aging avionics problem will not require a technology breakthrough.

General findings are presented first, followed by specific findings in four categories: management issues, budgetary issues, technical issues, and business issues. Because the Air Force is the sponsor of this study, the focus is on actions that should be taken by the Air Force. However, early on during the data-gathering phase of this study, it became readily apparent that the problem is not just internal to the Air Force. All of the services would benefit from a DoD enterprise strategy for dealing with aging avionics. Thus, recommendations are categorized as internal to the Air Force and external to the Air Force. External recommendations should be addressed in a multiservice context at the level of the Office of the Secretary of Defense.

GENERAL FINDINGS

Finding 1. The problem of aging avionics in military aircraft is large and growing. Unless it is addressed proactively and comprehensively, it will have a significant negative impact on the military readiness of U.S. forces.

Finding 2. The amount budgeted for the modernization of Air Force avionics systems is far short of the amount needed to pay for upgrades already approved in critical areas: performance and safety-mandated upgrades; avionics upgrades required for the global air traffic management (GATM) system; and replacements for aging avionics subsystems with the lowest reliability and/or highest repair costs.

Finding 3. A large number of organizations within DoD, the military services, and industry are attempting to address various aspects of the aging avionics problem. However, these efforts are poorly coordinated and often duplicative.

Finding 4. Widespread application of a MOSA to avionics architectures would enable DoD to manage the aging avionics problem more affordably, for both new aircraft and many legacy systems.

Finding 5. Most of the benefits of MOSA can be realized through a "modular" approach. Although a fully "open" system would have some additional advantages to the government in a few situations (as they do in certain commercial sectors where quantities and related factors can support a viable business case for this approach), most DoD acquisitions cannot justify a totally open approach. The "modular" aspect of MOSA, however, could be applied to virtually all DoD products.

SPECIFIC FINDINGS IN KEY AREAS

Government Management

Finding 6. There is no DoD-wide enterprise strategy, and only an embryonic Air Force-wide strategy, for dealing with the aging/obsolescent avionics problem. As a result, no enterprise management or leadership is addressing the problem on a full-time basis.

Finding 7. The Joint Technical Architecture (JTA) for defining weapon system architectures and standards extends beyond those needed for *inter*platform interoperability. The extension into *intra*platform standards is neither consistent nor integrated with MOSA approaches for addressing aging avionics. In fact, the JTA has shown an alarming reversion to the Military Specification (Mil Spec) era by requiring an onerous number of standards and specifications for *intra*platform avionics systems.

Finding 8. The technical expertise of DoD's depot support maintenance personnel in state-of-the-art avionics systems appears to be eroding as the workforce ages and retires.

Finding 9. As modifications and upgrades of aging avionics systems continue, aircraft, even of the same type, are being equipped with avionics systems with different compositions, capabilities and compatibilities, thus exacerbating the configuration-management problem.

Budgetary Issues

Finding 10. Long acquisition and upgrade cycles virtually require that avionics technology-refresh cycles be built into program plans during the engineering and manufacturing development phase prior to initial fielding.

Finding 11. Because of legal restrictions on the use of appropriated funds in various segregated accounts ("colors of money"), program managers are unable to address aging avionics problems in the most efficient way.

Finding 12. A comprehensive MOSA solution to the aging avionics problem could save money in the long run but would generally cost more than customized point solutions in the short run. This is particularly true for avionics upgrades in the legacy fleet.

Technical Issues

Finding 13. Implementation of MOSA would be facilitated by addressing the following needs:

- development of a common understanding of MOSA
- support for development of MOSA building codes, and disciplined design processes and related design tools required for MOSA implementation
- development of a test/requalification strategy coupled with the proper modeling and simulation tools to implement the MOSA strategy economically
- development of design-reuse databases and high-fidelity avionics models by original equipment manufacturers and suppliers

Business Issues

Finding 14. MOSA challenges the traditional military procurement model in several ways:

- With a modular, open-structured avionics system, DoD would, in theory, be able to solicit supplier competition at a variety of systems architecture levels: at the component level, the circuit-board level, the module level, or the subsystem level. The level must be high enough to provide incentives for qualified suppliers to participate, take advantage of local openness, and encourage suppliers to invest in research to improve avionics systems and stimulate innovation.
- The traditional mind-set of acquiring hardware and software will have to be changed to one of acquiring functionality (an approach in keeping with acquisition-reform precepts).
- The protection and value pricing of a supplier's intellectual property will be a key to success and will therefore require workable business models.
- Business incentives must be defined and provided to suppliers that will motivate a MOSA to avionics system design.

Finding 15. As DoD relies more heavily on commercial off-the-shelf hardware and software in avionics systems—and less on Mil Spec components and DoD-unique software languages—the expertise and intellectual property necessary to develop and maintain these systems will increasingly reside in the private sector.

RECOMMENDATIONS

Recommendations Specific to the Air Force

Recommendation 1. The Air Force, in coordination with the Office of the Secretary of Defense, should develop an "enterprise strategy" for dealing with the aging avionics problem. As a central feature of this strategy, the Air Force should mandate the creation of platform management/upgrade road maps with defined funding requirements for each weapon-system program.

Recommendation 2. The Air Force should raise the awareness in Congress about the shortfall in funding for avionics modernization by increasing its congressional

budget request to a level consistent with the modernization plans in system road maps.

Recommendation 3. The Air Force should require a modular, open-system design strategy for all new programs and upgrades, unless specifically waived. Emphasis should be on achieving the benefits of modularity rather than on complete openness, which often creates business or technical problems. A training program in MOSA concepts should be included for program managers, acquisition personnel, and support personnel. Contractors should be encouraged to use executable specifications as the primary archival documentation of the system; these specifications should be integrated into the avionics design environment.

Recommendation 4. The Air Force should continue to use the Quarterly Acquisition Program Reviews (QAPRs) as a forum for top-level oversight and, most important, for setting priorities to address the aging avionics problem.

Recommendation 5. The Air Force software and hardware testing community should develop a testing/requalification strategy tailored to modular avionics systems and should explore methods, including the use of high-fidelity simulation/emulation models and test beds, to minimize the impact on cost and schedule of requalifying avionics components and systems. The Air Force should build on the test strategy and simulation/emulation/diagnostic software model used by the Federal Aviation Administration in the commercial sector, which recognizes the value of reusing hardware/software and provides certification-test credit for reusable modules.

Recommendation 6. The Air Force should examine the feasibility of requiring, as a normal contractual deliverable, contractor-retained high-fidelity avionics simulation models as a means of minimizing validation/certification testing.

Recommendation 7. The Air Force should increase its support for the new Aging Aircraft System Program Office (SPO), in the Aeronautical Systems Center (ASC), by reinforcing its leadership and management responsibility for reducing the total ownership costs of new and legacy avionics systems.

Recommendation 8. The Air Force should develop and apply innovative contracting approaches that provide incentives for both government and contractors to reduce total ownership costs of avionics systems.

Recommendations That Apply to All of the Services

Recommendation 9. The Air Force should recommend that the Office of the Secretary of Defense develop an overall "enterprise strategy" for dealing with the aging avionics problem and issue a specific policy directive covering the following four points:

- A modular, open-system design strategy should be required for all new programs and upgrades, unless specifically waived.
- Development and use of program road maps should be mandatory for all Acquisition Category I (ACAT-I) programs (and their use encouraged for lesser programs); road maps should include funding plans and anticipated reductions in total ownership costs.
- Reviews by the Defense Acquisition Board (DAB) of these items should be a required acquisition milestone exit criteria.
- A revolving fund should be established (possibly the Working Capital Fund) to further front-end design/qualification of MOSA-compatible solutions to the problem of diminishing manufacturing sources.

Recommendation 10. The Air Force should recommend that OSD form joint working groups with industry to address policy and business concerns involved in the resolution of aging avionics problems:

- An industry/government steering group should be formed as a focal point for addressing the issues raised by MOSA procurement models and related modifications to the acquisition process, business/competitive models, intellectual property rights, management/pricing, the 50/50 rule, and related issues.
- The role of the Software Engineering Institute (SEI) could be expanded to include the development of MOSA building codes and design tools and processes; SEI could also recommend the process for defining and implementing interface standards at the proper point in the design cycle. The committee believes these changes would be consistent with current plans to reorganize SEI to consolidate software development, system

development, and integrated product team (IPT) activities.
- Congress should be encouraged to give DoD managers greater flexibility to shift funds among budget categories to take advantage of opportunities to reduce total ownership costs (TOCs).
- DoD should consider avenues to encourage young people to seek engineering educations focused on embedded software intensive systems and the maintenance of legacy systems.

Recommendation 11. The Air Force should recommend that OSD form a joint cross-platform working group (JCWG) at the flag-officer level to focus on reducing total ownership cost through the joint development of modular, scalable systems and the use of common solutions across weapon system platforms.

Recommendation 12. The Air Force should recommend that OSD examine and modify traditional defense procurement practices to minimize problems for avionics suppliers.

Recommendation 13. The Air Force should recommend that the current Open Systems Joint Task Force become the center of expertise and the focal point for addressing issues associated with the application of MOSA. Modularity, rather than total openness, should be emphasized to accommodate current business and technical issues.

Recommendation 14. The Air Force should recommend that the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics restrict applicability of the Joint Technical Architecture (JTA) and mandated standards to *inter*platform interoperability and allow the *intra*platform standards to be defined by a MOSA approach, along with a greatly reduced number of mandated standards.